

Command and Data	Console Position: CRONUS
Exploring Data and Statistical Inferences	

Command and Data System

How Does the Mission Control Center Command the International Space Station?

Instructional Objectives

Students will

- create a relative frequency histogram;
- correlate any gaps to the planned activities;
- determine skew;
- find mean, median, range and standard deviation;
- construct a boxplot; and
- correlate any outliers to the planned activities.

Degree of Difficulty

This problem requires students to integrate several aspects of the AP Statistics curriculum to obtain the solution. For the average AP Statistics student, the problem may be moderately difficult.

Total Time Required

Teacher Prep Time: 10–15 minutes

Class Time: 1 hour 5 minutes–1 hour 55 minutes

(To decrease amount of class time, students may complete research as homework via the Internet using the ISSLive! website or mobile application.)

- Introduction: 5–10 minutes
- Student Research: 25–45 minutes



ISSLive!

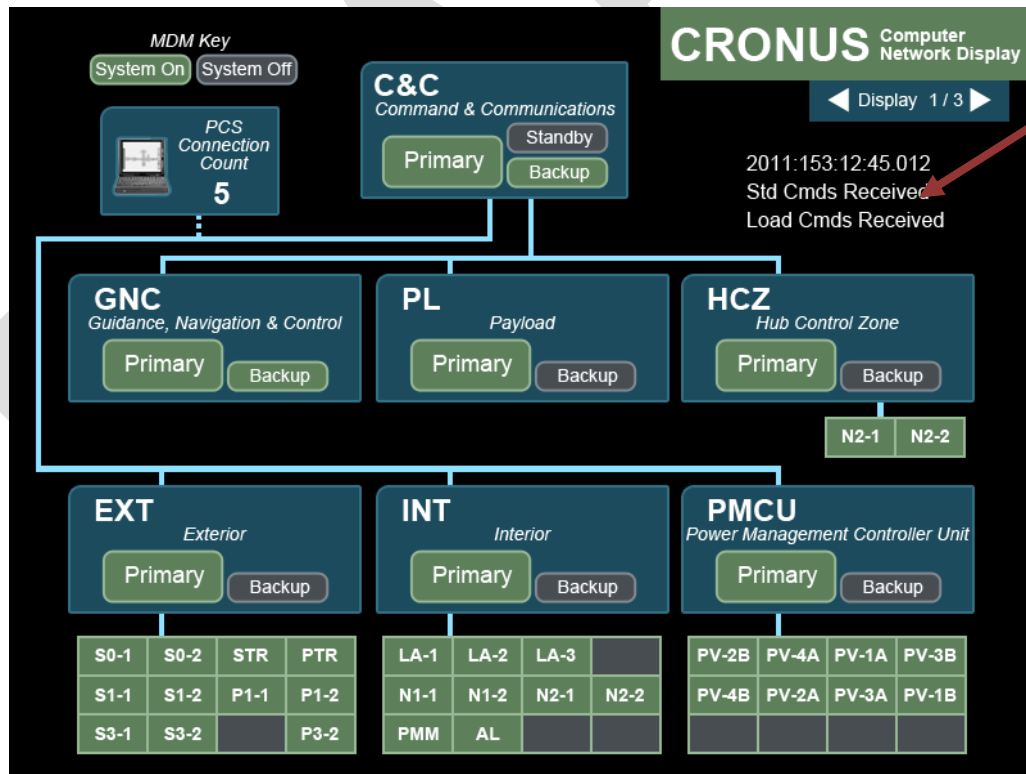
- Student Work Time: 25–45 minutes
- Post Conclusion: 10–15 minutes

Lesson Development

This problem is part of a series of problems associated with the NASA International Space Station *Live!* (ISSLive!) website at <http://spacestationlive.jsc.nasa.gov>.

Teacher Preparation

- Review the Command and Data System information on the ISSLive! website. This may be found at the *Operations* tab, under *Core Systems*.
- Review the Communication Radio Frequency Onboard Network Utilization Specialist (CRONUS) Handbook, paying specific attention to how commands are sent from the Mission Control Center (MCC) to the International Space Station (ISS). This handbook may be found at the CRONUS console position in the 3D Mission Control Center environment (under the *Interact* tab, then *Explore Mission Control*).
- Review the CRONUS console display in the 3D Mission Control Center environment and the live data associated with the Standard Command Counts data (indicated by the red arrow on the CRONUS console display graphic below). The displays may be accessed by clicking on the console screens.



CRONUS Console Display



- Review the interactive activity at the CRONUS console position in the 3D Mission Control Center environment *by clicking on the rocket* on top of the console. This activity demonstrates the communications network used to uplink commands to the ISS.
- Prepare copies of the STUDENT WORKSHEET (Appendix B).

Inquiry-Based Lesson (Suggested Approach)

1. Pose this question to the class:
How does the Mission Control Center (MCC) command the computer systems and the activities onboard the International Space Station?
2. Allow students to discuss the question in small groups or as a class. Have students build their own questions and possible solutions to the problem.
3. Distribute the STUDENT WORKSHEET to the class. Students may work individually or in small groups (2–3 members per group) to conduct the research. This may be assigned as homework.
4. In order to conduct the research, students should access the ISSLive! website and explore the 3D Mission Control Center. If needed, guide students to the CRONUS console position. They should access the CRONUS Handbook and CRONUS console displays, as well as the interactive activity, as they prepare to answer the questions on the STUDENT WORKSHEET.
5. Once the research is completed, students may work individually to complete the questions on the STUDENT WORKSHEET. They should refer to the live data on the CRONUS console displays located on the ISSLive! website to answer the entire problem.

Post Conclusion

6. A SOLUTION KEY (Appendix A) is provided below using data that is typical for normal operations of the Command and Data System. Students' answers will vary depending on the actual live data.
7. Have students discuss their answers in small groups or with the entire class and tie back to the original question:
How does the Mission Control Center (MCC) command the computer systems and the activities onboard the International Space Station?
8. Ask students to explain the Command and Data System and the data they used in their calculations.
9. Assessment of student work may be conducted by using the provided rubric (modeled after AP Free Response Question scoring).

Extension

Other possible uses for the ISSLive! website, focusing on CRONUS and the Command and Data System:

- Students can return to the data and observations to construct a 95% confidence interval to test the likelihood of their sample data results and perform the hypothesis test. This provides continuity in the students' statistical analyses.
- Revisit the CRONUS console position to check the live data at different times of the day, or when specific activities are scheduled, such as a reboost or spacewalk. (Check the timeline for activities, located under *Live Data*.)

AP Course Topics

Exploring Data: Describing Patterns and Departures from Patterns

- Constructing and interpreting graphical displays of distributions of univariate data (dotplot, stemplot, histogram, cumulative frequency plot)
 - Center and spread
 - Clusters and gaps
 - Outliers and other unusual features
 - Shape
- Summarizing distributions of univariate data
 - Measuring center: median, mean
 - Measuring spread: range, interquartile range, standard deviation
 - Measuring position: quartiles, percentiles, standardized score
 - Using boxplots
 - The effect of changing units on summary measures
- Exploring categorical data
 - Frequency tables and bar charts
 - Conditional relative frequencies and association
 - Comparing distributions using bar charts

Statistical Inference: Estimating population parameters and testing hypotheses

- Estimation (point estimators and confidence intervals)
 - Estimating population parameters and margins of error
 - Logic of confidence intervals, meaning of confidence level and confidence intervals, and properties of confidence intervals
 - Confidence interval for a mean
- Tests of significance
 - Logic of significance testing, null and alternative hypotheses

NCTM Standards

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them
 - Understand histograms, parallel boxplots, and scatterplots and use them to display data
 - Compute basic statistics and understand the distinction between a statistic and a parameter
- Select and use appropriate statistical methods to analyze data
 - For univariate measurement data, be able to display the distribution, describe its shape, and select and calculate summary statistics
 - Recognize how linear transformations of univariate data affect shape, center, and spread
- Develop and evaluate inferences and predictions that are based on data
 - Use simulations to explore the variability of sample statistics from a known population and to construct sampling distributions
 - Understand how sample statistics reflect the values of population parameters and use sampling distributions as the basis for informal inference

Contributors

This problem is part of a series of problems developed by the ISSLive! Team with the help of NASA subject matter experts.

Education Specialists

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Scoring Guide

Suggested 8 points total to be given.

Question		Distribution of points
1	4 points	All parts essentially correct
	3 points	Two parts essentially correct and one part partially correct
	2 points	Two parts essentially correct and no part partially correct or One part essentially correct and one or two parts partially correct or Three parts partially correct
	1 point	One part essentially correct and no parts partially correct or No parts essentially correct and two parts partially correct
2	4 points	All parts essentially correct
	3 points	Two parts essentially correct and one part partially correct
	2 points	Two parts essentially correct and no part partially correct or One part essentially correct and one or two parts partially correct or Three parts partially correct
	1 point	One part essentially correct and no parts partially correct or No parts essentially correct and two parts partially correct

SOLUTION KEY**COMMAND AND DATA SYSTEM****How Does the Mission Control Center Command the International Space Station?**

The Command and Data System is primarily monitored and controlled by the Communication Radio Frequency Onboard Network Utilization Specialist (CRONUS) flight controller. The CRONUS flight controller manages the transfer of data between communication satellites, which orbit the Earth, the International Space Station (ISS), ISS crewmembers, space vehicles visiting the ISS and the Mission Control Center (MCC). To learn more, explore the 3D ISS Mission Control Center by accessing Explore Mission Control under the *Interact* tab on the ISSLive! website at <http://spacestationlive.isc.nasa.gov>.

1. The number of commands that are uplinked from the MCC to the ISS is recorded by the MCC and displayed on a CRONUS console display. The command uplinks count from the MCC to the ISS is dependent on the activities currently being performed onboard the ISS. Visit the CRONUS console display and find the standard commands received, and then record the number of commands every two minutes for a twenty-minute period.

Below is a list of sample data points for the number of commands uplinked (data sent up from the MCC to the ISS) every two minutes using a recent download of commanding activities.

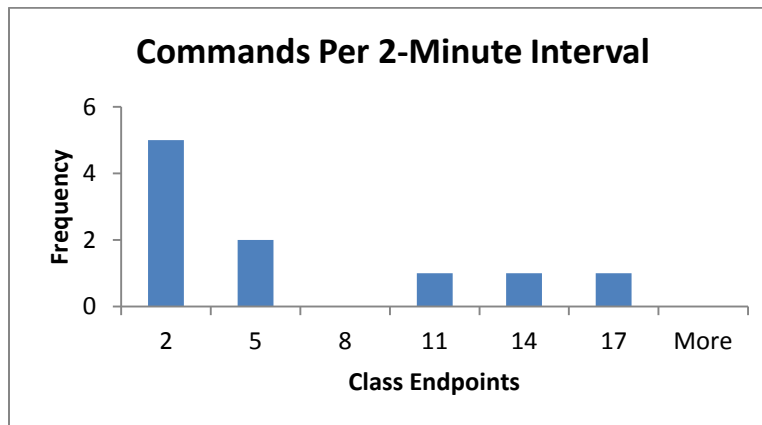
Assume the following number of commands every two minutes for a period of twenty minutes from the CRONUS console display:

1 2 0 0 17 14 9 3 4 0

- a. Based on the recorded number of commands, construct a sample distribution.

Class (Number of Commands Uplinked)	Class Midpoint	Class Frequency
0–2	1	5
3–5	4	2
6–8	7	0
9–11	10	1
12–14	13	1
15–17	16	1

- b. Display the distribution using a histogram (through Microsoft Excel® or another statistical application).



- c. Determine the direction of skew of the frequency distribution.

The data is definitely skewed to the right, or positively skewed. Therefore, the mean and median are to the right of the mode.

- d. Use the frequency distribution to determine:

- i. the central tendencies.

$$\text{mean} = 5$$

$$\text{median} = 2.5$$

$$\text{mode} = 0$$

- ii. the standard deviation.

$$s = \sqrt{\frac{\sum X^2 - (\sum \frac{X}{N})^2}{N - 1}}$$

$$s = \sqrt{\frac{596 - \frac{2500}{10}}{9}}$$

$$s = 6.200$$

- e. Construct a boxplot based on the data and determine the interquartile range of the distribution.



Minimum = 0; $Q_1 = 0$; $Q_2 = 2.5$; $Q_3 = 9$; Maximum = 17

- f. After analyzing the distribution of the boxplot, visit the *Crew Activities Timeline*. Based on the timeline and command uplinks, explain any activities that could account for the distribution of the data. Explain your answer.
- Extreme increases in commanding should correlate with ongoing activities, such as Robotic Arm operations. In this case, commands were being sent from the Payload Operations Integration Center to experiments on the ISS.
 - Extreme decreases in commanding activity should correlate with activities such as Extravehicular Activity (EVA), crew sleep time or during loss of signal.
2. Typically, an average of 3.8 commands is uplinked to the ISS every two minutes. Perform a hypothesis test for your sample data.
- State the null hypothesis and alternative hypothesis for the test.

$$H_0: \mu \leq 3.8; H_1: \mu > 3.8$$

Null hypothesis: The mean number of commands uplinked every two minutes is less than or equal to 3.8, per the population data.

Alternative hypothesis: The mean number of commands uplinked every two minutes is greater than 3.8, per the sample data.

- Determine the 95% confidence interval estimate for the true mean number of commands uplinked to the ISS per two-minute interval.

Level of significance = $\alpha = 0.05$; therefore the critical value $t = -1.833$

$$\text{Test statistic} = t = \frac{\bar{x} - \mu_x}{\frac{s}{\sqrt{n}}} = \frac{2.5 - 3.8}{\frac{6.2}{\sqrt{10}}} = -0.663$$

- Based on the above information, fail to reject or reject your alternative hypothesis. Justify your answer.

I must reject the null hypothesis due to the test statistic falling outside the critical region to the left of $t = -1.833$.

The ISS is manned 24 hours a day, 7 days a week. It requires daily maintenance and operation of the onboard systems, which is controlled by the Mission Control Center.

STUDENT WORKSHEET**COMMAND AND DATA SYSTEM****How Does the Mission Control Center Command the International Space Station?**

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Assume the following number of commands every two minutes for a period of twenty minutes from the CRONUS console display:

1 2 0 0 17 14 9 3 4 0

- a. Based on the recorded number of commands, construct a sample distribution.

- b. Display the distribution using a histogram (through Microsoft Excel® or another statistical application).

- c. Determine the direction of skew of the frequency distribution.
- d. Use the frequency distribution to determine:
 - i. the central tendencies.
 - ii. the standard deviation.
- e. Construct a boxplot based on the data and determine the interquartile range of the distribution.
- f. After analyzing the distribution of the boxplot, visit the *Crew Activities Timeline*. Based on the timeline and command uplinks, explain any activities that could account for the distribution of the data. Explain your answer.

2. Typically, an average of 3.8 commands is uplinked to the ISS every two minutes. Perform a hypothesis test for your sample data.
 - a. State the null hypothesis and alternative hypothesis for the test.
 - b. Determine the 95% confidence interval estimate for the true mean number of commands uplinked to the ISS per two-minute interval.
 - c. Based on the above information, fail to reject or reject your alternative hypothesis. Justify your answer.